

# ***U.S. PATENT APPLICATION***

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**Invention:** LIGHT-STABLE COLORED TRANSPARENT COMPOSITE FILMS

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# ***SPECIFICATION***

## **LIGHT-STABLE COLORED TRANSPARENT COMPOSITE FILMS**

### **FIELD OF THE INVENTION**

The present invention relates to colored transparent films. In particularly preferred forms, the present invention is embodied in colored transparent composite films which exhibit exceptional light stability (anti-fading) characteristics.

### **BACKGROUND AND SUMMARY OF THE INVENTION**

Transparent colored films are employed in a number of end-use applications, for example, as window films, light filters and the like. When employed as window films in the building and automotive industries, the colored transparent window films are typically adhered to glass window surfaces via a suitable adhesive so as to reduce the amount of near infrared, ultra-violet and/or visible radiation entering the building or automotive interior space. Such solar films therefore assist the occupants by providing less glare, reducing interior heating effects and the like.

Colored transparent films are typically provided by dyeing a suitable thermoplastic (preferably polyester) film substrate as is disclosed more completely in U.S. Patent Nos. 3,989,453; 3,943,105; 3,932,126; 4,050,892 and 4,047,889 (the entire content of each being incorporated expressly hereinto by reference). Thus, the thermoplastic film substrate may be preconditioned to enhance affinity to solvent or disperse dyes, followed by contacting the preconditioned film substrate with an organic dye-containing paste or solution.

Gray-toned (i.e., so-called "smoke-colored") transparent films are especially desirable in the market and are produced by suitable dyeing of the film substrates using the necessary proportions of red, blue and yellow organic dyes. One problem which these conventional gray-toned transparent films experience, however, is that the yellow dye component is more susceptible to light degradation as compared to the red and blue dye components. Thus, over prolonged exposure to light, the yellow dye component of the gray-toned dyed film tends to decompose (fade) thereby changing the visual appearance of the film undesirably to a more purple color tone due to the then more dominant presence of the red and blue dyes remaining in the dyed film.

It would therefore be especially desirable if colored (dyed) transparent thermoplastic films could be rendered more light stable thereby minimizing (or preventing entirely) fading and/or changing color tones over time. It is towards fulfilling such a need that the present invention is directed.

Broadly, the present invention is embodied in composite film structures exhibiting a predetermined finished color tone comprised of a transparent film layer which exhibits a color deficiency as compared to the finished color tone, and a pigment which is visually associated with, and satisfies the color deficiency of, the film layer. Most preferably, the pigment is provided as a homogenous dispersion in a transparent color-matching layer positioned adjacent to the film layer. Thus, when the film and color-matching layers are viewed collectively as a unit, the perceived color tone will be that of the finished predetermined color tone. In other words, the color-matching layer provides visually an additive effect on the perceived color of the composite film structure.

As a practical matter, therefore, the color deficiency of the film layer can be selected to be that particular dye which is more light unstable and thereby more likely to degrade over time when exposed to light. The pigment in the color-matching layer (which would inherently be more color  
5 stable as compared to the dye) may then be selected to satisfy the color deficiency in the film layer. As a result, a more light stable transparent color film composite structure ensues (i.e., due to the lesser amount (if any) of more light unstable dye(s) in the film and the greater amount of more light stable pigments in the adjacent color-matching layer).

10 These and other aspects and advantages of the present invention will become more clear after careful consideration is given to the following detailed description of the preferred exemplary embodiments.

#### **BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWINGS**

The file of this patent contains at least one drawing executed in  
15 color. Copies of this patent with color drawing(s) will be provided by the Patent and Trademark Office upon request and payment of the necessary fee.

Reference will hereinafter be made to the accompanying drawings, wherein like reference numerals throughout the various FIGURES denote  
20 like elements, and wherein,

FIGURE 1 is a greatly enlarged schematic cross-section of one embodiment of a composite film in accordance with the present invention;

FIGURE 2 is a greatly enlarged schematic cross-section of the composite film depicted in FIGURE 1 applied onto a glass substrate;

FIGURE 3 is a greatly enlarged schematic cross-section of another embodiment of a composite film in accordance with the present invention;

FIGURE 4 is a greatly enlarged schematic cross-section of yet another embodiment of a composite film in accordance with the present invention;

FIGURES 5-9 are graphical representations of the color stability test data obtained by the Example 2 below; and

FIGURES 10-13 are color photoprints each visually depicting the non-weathered finished color tone (visible on left-hand side of each sample) and the results of accelerated weather testing (visible on the right-hand side of each sample) on such finished color tone obtained according to Example 2 below, wherein FIGURE 10 is a sample in accordance with the present invention, and FIGURES 11-13 are each representative of commercially available transparent colored films.

## **DETAILED DESCRIPTION OF THE INVENTION**

### **I. Definitions**

The terms "hue", "chroma" (sometimes referred to in the art as intensity of color saturation) and "value" are the color coordinates associated with the Munsell color system (see U.S. Patent No. 824, 374, the entire content of which is incorporated fully hereinto by reference).

The term "colorant" is any material which exhibits hue, chroma and/or value. Thus, a colorant may be one which exhibits a perceived color (e.g. red, blue and/or yellow) in which case it has a definite hue and/or chroma and is characterized as being chromatic. A colorant may also be a material which lacks both hue and chroma, but which

nonetheless contributes to the value coordinate, in which case it is characterized as achromatic.

A "pigment" is a particulate material which is a colorant.

5 The term "transparent" connotes the ability to perceive visually an object, indicia, words and the like through a medium, which is a film in the preferred embodiment of this invention. More specifically, the term "transparent" as used herein and in the accompanying claims means the medium (e.g., film) exhibits a haze value (ASTM D 1003-61) of not greater than about 25%, preferably not greater than about 5%, and a  
10 visible light transmission (VLT) through the film structure (ASTM E903 and NFRC 300-93, "Procedure for Determining the Solar Optical Properties for Simple Fenestration Products") of between about 1% to about 90%, preferably between about 5% to about 80%, and most preferably between about 5% to about 50%. The particular haze value  
15 and VLT of a film structure will thus depend on its intended end use application. For example, window films for use with automotive glass will typically have a relatively low haze value (e.g., not greater than 5%) and a relatively high VLT (e.g., between about 5 to about 50%). Film structures intended for shade applications, however, can tolerate relatively greater  
20 haze values and relatively lower VLT as compared to automotive window films.

## **II. Detailed Description of the Preferred Embodiments**

Accompanying FIGURE 1 shows an enlarged schematic cross-section of one embodiment of a composite film 10 having a finished color  
25 tone in accordance with the present invention. Specifically, the composite film 10 necessarily includes a film layer 12 and a color-matching layer 14. The film layer 12 is formed of a suitable thermoplastic, preferably a

polyester, such as polyethylene terephthalate (PET), or other suitable thermoplastics, such as, for example, polyacrylic, polyimides, polyamides (e.g., nylons), and polyolefins (e.g., polypropylenes, polyethylenes and the like). The thermoplastic films employed in the practice of this invention  
5 can include conventional additives either coated upon, or homogeneously blended within, the film. Thus, the thermoplastic films may include UV-absorbers, stabilizers, fillers, lubricants and other processing aids, and the like.

The thickness of film layer 12 is most advantageously between  
10 about 0.25 mil to 14 mils. For example, when composite film 10 is employed as a solar film for windows, the thickness of film layer 12 is typically in the range between about 0.5 to about 1.0 mil. When the composite film 10 is employed for other applications, such as a sun shade, the thickness of film layer 12 may be between about 1.0 mil to  
15 about 3.0 mils.

The film layer 12 may be uncolored or colored. If uncolored, then the film layer 12 will exhibit a complete deficiency in all three color coordinates of hue, chroma and value. If colored, then the film layer 12 will exhibit a deficiency in a least one color coordinate of hue, chroma and  
20 value as compared to the finished color tone of the composite film 10. In either the uncolored or colored case, therefore, the film layer 12 will exhibit a deficiency in at least one of hue, chroma and value as compared to the finished color tone of the composite film 10.

The color deficiency of the film layer 12 is satisfied in the color-  
25 matching layer 14. Specifically, the color matching layer 14 includes a homogeneous dispersion of pigment therein which satisfies the color deficiency in the film layer 12. As a result, when the film and color-

matching layers 12, 14 are viewed collectively, the additive effect of their respective color tones will result in a visual perception corresponding to the finished color tone of the composite film 10. Most preferably, the color-matching layer is interior of the film layer 12 (i.e., positioned closer to the sunlight than the film layer 12).

In the composite film 10 shown in FIGURE 1, the color-matching layer 14 is most preferably formed by dispersing the pigment throughout a mounting adhesive. Virtually any suitable pressure or non-pressure sensitive mounting adhesive may be employed in the practice of the present invention which allows the composite film 10 to be adhered securely to a desired support substrate. In this regard, the preferred mounting adhesive is an acrylic pressure sensitive adhesive commercially available from Solutia, Inc. under the tradename GELVA<sup>®</sup> 263 adhesive which is supplied as an acrylic resin solution.

The pigment that is employed in the practice of the present invention is broadly characterized as a particulate colorant material. That is, the pigment will impart a desired color tone to the color-matching layer and is selected based on its color characteristics of hue, chroma and/or value as well as its average particle size properties. Thus, the pigment employed in the present invention can be either chromatic in that it has at least one of hue and chroma characteristics, or can be achromatic in which case it is lacking in both hue and chroma characteristics but has a value characteristic. The pigment also cannot have too large a particle size as this would adversely scatter light making the composite film less transparent (i.e., more hazy, translucent or opaque). Therefore, the pigment employed in the practice of the present invention is required to have an average particle size of less than about 0.50  $\mu\text{m}$ , more preferably less than about 0.10  $\mu\text{m}$ , and most preferably less than about 0.05  $\mu\text{m}$ .



Virtually any pigment that satisfies the above-noted criteria may be employed in the practice of this invention. Thus, pigments based on iron oxide, lead, chrome, ultramarine, iron blue, cadmium and the like may be employed. For example, when the color deficiency in the film layer 12 is  
5 with respect to the yellow hue and/or chroma, then a particularly preferred pigment is red iron oxide (which actually visibly has a yellowish color tone).

When employed as a dispersion within the mounting adhesive, the pigments employed in the practice of the present invention may  
10 conveniently be mixed with the adhesive so as to be homogeneously dispersed therein and then applied onto the film layer 12 as the color-matching layer 14 in any known manner, such as dipping, spraying, padding, roller coating, gravure coating, printing or the like. Following application, the color-matching layer 14 (i.e., the adhesive material  
15 containing a homogenous dispersion of pigment therein) may be covered by a suitable release layer 18 to allow the composite film 10 to be handled and shipped prior to being mounted onto a substrate. In this regard, just prior to use, the release layer 18 will be removed or peeled away from the adhesive (color-matching) layer 14 thereby leaving the remaining  
20 laminated components of the composite film (noted by reference numeral 10' in FIGURE 2). The composite film components 10' may then be affixed to a substrate, for example, a glass substrate (e.g., a building or automotive window) 20 as shown in FIGURE 2.

One particularly preferred embodiment of the present invention is a  
25 gray-toned composite film having a film layer 12 which is colored with predominantly red and blue dyes and thus will exhibit a yellow color deficiency (i.e., will exhibit a purple-like color tone). Thus, the preferred gray-toned composite may be dyed with a minor, but insufficient, amount

(if any) of a yellow dye. The color-matching layer 14 will thus be formed of a mounting adhesive in which a yellow-colored pigment (e.g., an iron oxide) is dispersed homogeneously. Thus, the yellow-colored pigment in the color-matching layer 14 will satisfy the yellow color deficiency of the dyed film layer 12.

The composite film 10 may also include an exterior (i.e., relative to the rigid substrate, typically glass, on which the film is adhered) polymeric protective coating 16 (typically called a "hardcoat" in art parlance). The protective coating 16 serves to impart abrasion resistance, scratch and/or chemical resistance to the composite film 10 or 10'. Typically, such coatings are curable either thermally or by radiation and can be, for example, highly cross-linked acrylic acid esters. Particularly preferred materials that may be employed in the protective coating 16 are the radiation polymerizable acrylic coatings disclosed more fully in U.S. Patent No. 4,557,980 (the entire content of which is expressly incorporated hereinto by reference). If present, the protective coating 16 will typically have a thickness of less than 10  $\mu$ , and preferably between about 1  $\mu$  to about 4.5  $\mu$ .

Although the composite film 10 has been described wherein the pigment is dispersed throughout an adhesive material so as to form the color-matching layer 14, it may be desirable to disperse some (or all) of the pigment in the protective coating 16, in which case both the layers 14 and 16 (or just the layer 16) constitute the color-matching layer to satisfy the color deficiency of the film layer 12. Furthermore, it is possible that the pigment could be dispersed throughout, and thus be integrally provided with, the film layer 12. The film layer 12 with its integral dispersion of pigment could then be dyed to have a color deficiency which is integrally satisfied by the pigment contained therewithin.

Accompanying FIGURE 3 shows another embodiment of a composite film 30 according to the present invention. In this regard, like the composite film 10 discussed above, the composite film 30 includes a thermoplastic (preferably PET) film layer 12, a color-matching adhesive layer 14 containing a pigment dispersed therein, a protective exterior coating 16, and a release layer 18 covering the adhesive color-matching layer 14. However, according to the embodiment depicted in FIGURE 3, the composite film 30 is provided with another film layer 32 which is adhered to the film layer 12 by a suitable laminating adhesive layer 34.

The film layer 32, like the film layer 12 may be uncolored or colored as may be desired. Furthermore, the film layer 32 may be metallized. That is, the film layer 32 may be provided with a relatively thin metal coating, e.g., aluminum, nickel alloys (e.g., nickel-chromium alloys or their oxides), silver, titanium and the like, applied by conventional vacuum deposition techniques. If present, the metallized layer will typically have a thickness of between about 50Å to about 600Å.

The pigment in the adhesive color-matching layer 14 may alternatively, or additionally, be provided in the laminating adhesive layer 34, if desired. Thus, the pigment may be distributed among the layers 16, 14 and 32, or be contained in any one of such layers as may be desired. For example, as shown in FIGURE 4, a laminated composite film 40 is provided with thermoplastic film layers 42 and 44 laminated to one another with a suitable adhesive layer 46. One or both of the film layers 42, 44 may thus be dyed in a manner which provides for a color deficiency as compared to the finished color tone of the composite film 40. A pigment satisfying the criteria noted previously may thus be dispersed homogeneously throughout the adhesive layer 46 so as to

satisfy the color deficiency of the film layers 42 and/or 44. The composite film 40 depicted in FIGURE 4 is thus suitable as a window shade film.

The transparent films according to the present invention can be "engineered" to provide desired light transmission characteristics, depending on the end-use application. Most preferably, the colored transparent composite films will have a visible light transmission (VLT) of between about 1% to about 90%, preferably between about 5% to about 80%, and most preferably between about 5% to about 50%. The transparent films of this invention will also most preferably exhibit haze values of not greater than about 25%, preferably not greater than about 5%.

### III. Examples

The present invention will be further understood after consideration is given to the following non-limiting Examples.

#### 15        Example 1

A red iron oxide (CI R101) pigment was blended with a scratch-resistant methyl methacrylate hardcoat material (U.S. Patent No. 4,557,980) using methyl iso-butyl ketone (MIBK) solvent in an amount of 1 wt.% iron oxide in the hardcoat plus MIBK. The resulting mixture had CIE lab values ( $10^0$  standard observer and D65 light source) of  $L^* = 94.18$  /  $a^* = 0.84$  /  $b^* = 9.25$  and was applied at a thickness of 1.0-1.5 microns using standard gravure coating methods onto a dyed polyester film so as to achieve a gray color tone. CIE Lab values ( $10^0$  observer with D65 light source) for the resulting coated film were:  $L^* = 81.13$  /  $a^* = -3.96$  /  $b^* = -4.9$ . The coated film was mounted on clear, single strength glass using an acrylic pressure sensitive adhesive (GELVA 263 adhesive, Solutia, Inc.) which contained a benzophenone UV-absorber. The film and glass

structure was then subjected to accelerated Xenon weather testing according to ASTM G26-93. The film showed enhanced color stability characteristics after 1200 hours exposure to the Xenon weather testing conditions.

5                    **Example 2**

                  A red iron oxide (CI R101) pigment was blended in an amount of 1 wt.% with an acrylic pressure sensitive adhesive (GELVA® 263 adhesive; Solutia, Inc.) which contained a benzophenone UV-absorber. The resulting blend of red iron oxide pigment and adhesive was used to mount  
10                the same dyed gray-tone polyester film employed in Example 1 to a clear, single strength glass for weather testing according to ASTM G26-93.

                  The results of the weather testing on the composite film in accordance with the present invention were compared to the weather testing results of three dyed polyester film products commercially  
15                available from CPFilms, Inc. of Martinsville, VA, identified by AT 35 Gr SR HPR (Comp. 1), AT 35 Ch SR HPR (Comp 2) and AT 35 Bz SR PS (Comp 3). The results of such comparative testing are shown graphically in the accompanying FIGURES 5-9. In addition, the results of the accelerated weather testing are shown photographically in accompanying  
20                FIGURES 10-13. In this regard, the left-hand side of each of FIGURES 10-13 represents the finished color tone of the film unexposed to the weather testing conditions, whereas the right-hand side of FIGURES 10-13 was exposed to, and thus depict the condition of the film after, weather testing. As is evident, the composite film in accordance with the invention  
25                (FIGURE 10) shows enhanced color stability characteristics as compared to the conventional films Comp. 1 (FIGURE 11), Comp. 2 (FIGURE 12) and Comp. 3 (FIGURE 13).

**Exempl 3**

Example 2 was repeated except that the 1 wt.% iron oxide containing adhesive was used to laminate a metallized film (1 mil thick aluminum metallized layer on a 15% visible light transmission gray-toned dyed polyester film) to a .5 mil thick clear polyester film containing UV absorbers. The resulting laminated composite film structure was mounted to a single strength glass using a non-pigmented acrylic pressure sensitive adhesive (GELVA<sup>®</sup> 263 adhesive, Solutia, Inc.) which contained a benzophenone UV-absorber. Following weather testing, the sample was visually observed for corrosion and coating instability with no significant anomalies being detected.

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While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not to be limited to the disclosed embodiment, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.